(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 236 985 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
04.09.2002 Bulletin 2002/36

(51) Int Cl.7: G01M 11/00

(21) Application number: 02251193.5

(22) Date of filing: 21.02.2002

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: 02.03.2001 JP 2001058538

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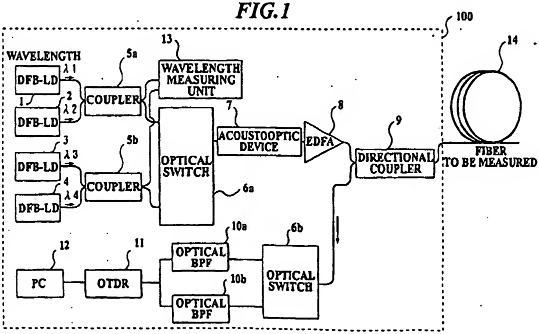
(54) Apparatus and method for measuring chromatic dispersion distribution

(57) A chromatic dispersion distribution measuring apparatus which can determine a sign of a dispersion value, and a measuring method thereof. The chromatic dispersion distribution measuring apparatus comprises: a plurality of light sources (1-4) for emitting lights having different wavelengths; an intensity measuring section for measuring a light intensity of a four-wave mixed light caused by any two lights, as a function of a transmission distance; a chromatic dispersion calculating section for calculating a chromatic dispersion value of the optical device, in accordance with the light intensity; a time measuring section for measuring a propagation time of a reflected light caused by each light; and a sign determining section for determining a sign of the chromatic dispersion value of the optical device, on the basis of two different chromatic dispersion values and two propagation times of reflected lights of two lights related to the two chromatic dispersion values.

FIG.1



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a chromatic dispersion distribution measuring apparatus for measuring a chromatic dispersion distribution in an optical device to be measured, such as an optical fiber, and a measuring method thereof.

Description of Related Art

[0002] In recent years, in order to satisfy demands for higher speed information communications, optical communication systems using optical fibers have been constructed. One of the factors in preventing the higher speed signal transmission and the longer distance transmission in the above optical communication systems, is the chromatic dispersion. The chromatic dispersion is a phenomenon caused by the factor that the speeds of lights transmitted through a medium vary according to the wavelengths of the lights. In the construction of the optical communication systems, it is necessary to grasp the chromatic dispersion characteristic in detail.

[0003] A chromatic dispersion distribution measuring apparatus for measuring the above chromatic dispersion is disclosed in, for example, Japanese Patent Application Publication No. Tokukai-Hei 10-83006 (corresponding to the United States Patent No. 5,956,131 and the European Patent Application No. 0819926A2). In the publication, the chromatic dispersion distribution measuring apparatus measures the dispersion distribution in a longitudinal direction of a fiber to be measured, as follows. Two lights having different wavelengths from each other are inputted into the fiber to be measured. A specific wavelength component is extracted by an optical band-pass filter from a four-wave mixed light caused by the interaction between backscattered lights of the two lights. A light having the extracted specific wavelength component is inputted into an Optical Time Domain Reflectometer (OTDR).

[0004] The Four-Wave Mixing (FWM) is a phenomenon caused by the non-linearity of a plurality of lights having different wavelengths from each other in an optical fiber. For example, when two lights have wavelengths $\lambda 1$ and $\lambda 2$ respectively, a wavelength $\lambda 3$ of a light (Stokes ray) caused by this phenomenon and a wavelength $\lambda 4$ of a light (anti-Stokes ray) caused by the phenomenon satisfy the following equation (1).

$$\lambda 2 - \lambda 1 = \lambda 1 - \lambda 4 = \lambda 3 - \lambda 2 \qquad (1)$$

[0005] However, in such a chromatic dispersion distribution measuring apparatus according to an earlier development, there are some problems as follows.

[0006] The above-described dispersion distribution measured by the above-described OTDR generally has the different value according to the fiber to be measured, and the fixed sign (positive (+) or negative (-)) to a random wavelength of inputted lights for every fiber to be measured. That is, the sign of the dispersion value is determined according to the fiber to be measured, regardless of the wavelength of the inputted light.

[0007] However, because the chromatic dispersion distribution measuring apparatus according to an earlier development, can measure only the absolute value of the above dispersion value, in order to measure the sign of the dispersion value, it is necessary to further provide a measuring apparatus for measuring the sign of the dispersion value besides the chromatic dispersion distribution measuring apparatus. Therefore, because the whole measuring apparatus including the chromatic dispersion distribution measuring apparatus according to an earlier development becomes complex, it has been desired that the functionality thereof is improved.

SUMMARY OF THE INVENTION

[0008] In order to solve the above-described problems, an object of the present invention is to provide a chromatic dispersion distribution measuring apparatus which can determine the sign of the dispersion value, and a measuring method thereof.

[0009] In accordance with a first aspect of the present invention, a chromatic dispersion distribution measuring apparatus (for example, an optical fiber chromatic dispersion distribution measuring apparatus 100 shown in FIG. 1), comprises:

a plurality of light sources (for example, four DFB-LDs 1 to 4 shown in FIG. 1) for emitting lights having different wavelengths from each other;
an intensity measuring section (for example, an OTDR 11 shown in FIG. 1) for measuring a light intensity of a four-wave mixed light which is caused by any two lights of lights emitted from the plurality of light sources and which is outputted from an optical device to be measured, as a function of a transmission distance in the optical device, when the two lights are inputted into the optical device;
a chromatic dispersion calculating section (for example, a PC 12 shown in FIG. 1) for calculating a chromatic dispersion value of the optical device, in accordance with the light intensity measured by the intensity measuring section, as the function of the transmission distance;
a time measuring section (for example, a PC 12 shown in FIG. 1) for measuring a propagation time of a reflected light which is caused by each light of lights emitted from the plurality of light sources and which is transmitted from a predetermined point in the optical device, when each light is inputted into

the optical device; and

e sign determining section (for example, a PC 12 shown In FIG. 1) lor determining e sign of the chromatic dispersion velue of the optical device, on the basis ol two different chrometic dispersion velues calculeted by the chromatic dispersion calculeting section, and two propagation times of reflected lights caused by two lights related to the two chrometic dispersion velues respectively, of lights emitted from the plurelity of light sources.

[0010] In accordance with a second aspect of the present Invention, e chromatic dispersion distribution measuring method, comprises:

emitting e plurallty of lights heving different wavelengths from eech other;
meesuring a light Intensity of a four-wave mixed light which is caused by any two lights of the plurality of lights and which Is outputted from an optical device to be measured, as a function of a transmission distance In the optical device, when the two lights are inputted into the optical device;
calculating a chromatic dispersion value of the optlcel device, in accordence with the light intensity measured as the function of the trensmission distance;
measuring e propegation time of e reflected light which is caused by eech light of the plurality of lights end which Is transmitted from e predetermined point In the optical device, when each light is Inputted Into the optical device; and
determining a sign of the chromatic dispersion value of the optical device, on the besis of two different chrometic dispersion values and two propagation times of reflected lights ceused by two lights releted to the two chrometic dispersion velues respectively, of the plurelity of lights.

[0011] In eccordance with a third aspect of the present Invention, e chromatic dispersion distribution measuring apparatus, comprises:

et least four light sources for emitting lights heving different wevelengths from each other;
en intensity measuring section for measuring two different light intensities of two four-wave mixed lights which are caused by any two pairs ol lights of lights emitted from the light sources and which ere outputted from en optical device to be measured, as functions of transmission distences In the optical device, when the two pairs of lights ere Inputted Into the optical device, for every pair of lights;
e chrometic dispersion calculating section for celculeting two different chromatic dispersion values of the opticel device, in eccordance with the two light intensities meesured by the Intensity measuring section, respectively;
e time measuring section for measuring two different propagation times of two reflected lights one of which is caused by any one light of one pair of the two pairs of lights and transmitted from e predetermined point In the optical device, end the other of which is caused by any one light of the other pair of the two pairs of lights and transmitted from a predetermined point in the optical device, when the one light of the one pair of lights end the one light of the other pelr of lights are individuelly inputted into the optical device; and
a sign determining section for determining a sign of the chrometic dispersion value of the optical device, on the basis of the two chromatic dispersion values calculated by the chromatic dispersion calculeting section, and the two propegetion times measured by the time measuring section.

[0012] In accordance with a fourth espect of the present Invention, a chromatic dispersion distribution meesuring method, comprises:

emitting at least four lights heving different wavelengths from each other;
measuring two different light intensities of two four-wave mixed lights which ere caused by eny two pairs of lights of the lights end which ere outputted from en opticel device to be measured, as functions of transmission distances in the opticel device, when the two peirs of lights are inputted into the optical device, for every pelr of lights;
calculating two different chromatic dispersion values of the optical device, in accordance with the two light Intensities, respectively;
measuring two different propegetion times of two reflected lights one of which is caused by any one light of one pair of the two pairs of lights and transmitted from e predetermined point In the optical device, and the other of which is caused by eny one light of the other pelr of the two pairs of lights and transmitted from a predetermined point in the optical device, when the one light of the one pelr of lights end the one light of the other pelr of lights are individuelly inputted into the opticel device; end
determining e sign of the chromatic dispersion value of the optical device, on the basis of the two chromatic dispersion values and the two propagation times.

[0013] According to the first, second, third or fourth aspect of the present invention, it is possible to realize a chromatic dispersion distribution meesuring epperatus heving e high functioneliity, without providing an epparatus for determining the sign of the chromatic dispersion value of the optical device to be measured, to the chromatic dispersion distribution meesuring apperatus.

[0014] Preferably, the chromatic dispersion distribution measuring apparatus according to the first aspect

of the present invention, further comprises:

a chromatic dispersion distribution calculating section for calculating a chromatic dispersion distribution with a sign, of tha optical device, in accordance with the sign of the chromatic dispersion value of the optical device, determined by the sign determining section.

[0015] Preferably, the chromatic dispersion distribution measuring method according to the second aspect of the present invention, further comprises:

calculating a chromatic dispersion distribution with a sign, of the optical device, in accordanca with the sign of tha chromatic dispersion valua of the optical device.

[0016] Preferably, the chromatic dispersion distribution measuring apparatus according to the third aspect of the prasent invention, further comprises:

a chromatic dispersion distribution calculating section for calculating a chromatic dispersion distribution with a sign, of the optical device, in accordanca with the sign of the chromatic dispersion value of tha optical device, determinad by the sign determining section.

[0017] Preferably, tha chromatic dispersion distribution measuring method according to the fourth aspect of the present invention, further comprises:

calculating a chromatic dispersion distribution with a sign, of the optical device, in accordance with the sign of the chromatic disparsion value of the optical device.

[0018] According to the apparatus or mathod as describad above, it is possible to measure the chromatic dispersion distribution on the basis of the sign of the chromatic dispersion value of the optical device to be measured, without providing an apparatus for determining the sign of the chromatic dispersion value of the optical device to be measured, to the chromatic dispersion distribution measuring apparatus. Consequently, it is possible to realize a chromatic dispersion distribution measuring apparatus having a further high functionality of outputting correct chromatic dispersion distribution data.

[0019] Preferably, the chromatic dispersion distribution measuring apparatus according to the third aspect of the present invention, further comprises:

a first optical switching section for providing any two pairs of lights of lights emitted from the light sources, for every pair of lights, and any one light of one pair of the two pairs of lights and any ona light of tha other pair of the two pairs of lights, individually, to the optical davica; and

a second optical switching section for providing two four-wave mixed lights caused by tha two pairs of lights, to the intensity measuring section , individually, and two reflected lights caused by the one light of tha one pair of the two pairs of lights and the one light of the other pair of the two pairs of lights, to the time measuring section, individually.

[0020] Preferably, the chromatic dispersion distribution maasuring method according to the fourth aspect of the present invantion, furthar comprises:

providing any two pairs of lights of the lights, for every pair of lights, and any ona light of one pair of the two pairs of lights and any one light of the other pair of the two pairs of lights, individually, to the optical device; and

providing two four-wave mixed lights caused by the two pairs of lights, individually, to measure two different light intensities, and two reflected lights caused by the one light of the one pair of the two pairs of lights and the one light of the other pair of tha two pairs of lights, individually, to measure two different propagation times.

[0021] In accordance with a fifth aspect of the present invention, a chromatic dispersion distribution measuring apparatus, comprises:

means for emitting at least four lights having different wavelengths from each other;

means for maasuring two different light intensities of two four-wave mixed lights which ara caused by any two pairs of lights of the lights and which are outputted from an optical device to be measured, as functions of transmission distances in the optical devica, when the two pairs of lights are inputted into tha optical davice, for every pair of lights;

means for calculating two different chromatic disparsion values of the optical device, in accordance with the two-light intensities, respectively;

means for measuring two different propagation times of two reflected lights one of which is caused by any one light of one pair of the two pairs of lights and transmitted from a predetermined point in the optical device, and the other of which is caused by any one light of the othar pair of the two pairs of lights and transmitted from a predetermined point in tha optical device, when the one light of the one pair of lights and the one light of the other pair of lights are individually inputted into the optical device; and

means for determining a sign of the chromatic dispersion value of the optical device, on the basis of the two chromatic dispersion values and the two propagation times.

[0022] Preferably, the chromatic dispersion distribution measuring apparatus according to the fifth aspect of the present invention, further comprises:

means for calculating a chromatic dispersion distribution with a sign, of the optical device, in accordance with the sign of the chromatic dispersion value of the optical device.

[0023] Preferably, the chromatic dispersion distribution measuring apparatus according to the fifth aspect of the present invention, further comprises:

means for providing any two pairs of lights of the lights, for every pair of lights, and any one light of one pair of the two pairs of lights and any one light of the other pair of the two pairs of lights, individually, to the optical device; and
means for providing two four-wave mixed lights caused by the two pairs of lights, individually, to measure two different light intensities, and two reflected lights caused by the one light of the one pair of the two pairs of lights and the one light of the other pair of the two pairs of lights, individually, to measure two different propagation times.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not intended as a definition of the limits of the present invention, and wherein;

FIG. 1 is a block diagram showing a structure of an optical fiber chromatic dispersion distribution measuring apparatus 100 to which the present invention is applied;
FIG. 2 is a graph showing an intensity distribution of a FWM light outputted from an OTDR 11 of the optical fiber chromatic dispersion distribution measuring apparatus 100 shown in FIG. 1;
FIG. 3 is a flow chart for explaining a process for calculating a chromatic dispersion distribution in a fiber 14 to be measured, in the optical fiber chromatic dispersion distribution measuring apparatus 100 shown in FIG. 1; and
FIG. 4 is a flow chart for explaining a process for determining a sign of the chromatic dispersion distribution in the optical fiber chromatic dispersion distribution measuring apparatus 100 shown in FIG. 1.

PREFERRED EMBODIMENT OF THE INVENTION

[0025] Hereinafter, an embodiment of the present invention will be explained in detail with reference to FIGS. 1 to 4.

[0026] Firstly, the structure of the embodiment will be explained.

[0027] FIG. 1 is a block diagram showing a structure of an optical fiber chromatic dispersion distribution measuring apparatus 100 to which the present invention is applied.

[0028] In FIG. 1, the optical fiber chromatic dispersion distribution measuring apparatus 100 comprises four distributed feedback-laser diodes (DFB-LD) 1 to 4, two couplers 5a and 5b, two optical switches 6a and 6b, an acoustooptic device 7, an erbium-doped fiber amplifier (EDFA) 8, a directional coupler 9, two optical bandpass filters (BPF) 10a and 10b, an optical time domain reflectometer (OTDR) 11, a personal computer (PC) 12, a wavelength measuring unit 13, and so on. Further, a fiber 14 to be measured is connected with the directional coupler 9 of the optical fiber chromatic dispersion distribution measuring apparatus 100.

[0029] The DFB-LDs 1 and 2 are light sources. The DFB-LD 1 emits a light having a wavelength λ1. The DFB-LD 2 emits a light having a wavelength λ2 which is different from the wavelength λ1. The lights emitted from the DFB-LDs 1 and 2 are inputted to the optical switch 6a through the coupler 5a connected to the DFB-LDs 1 and 2.

[0030] The DFB-LDs 3 and 4 are light sources provided in order to determine the sign of the chromatic dispersion value of the fiber 14 to be measured. The DFB-LD 3 emits a light having a wavelength λ3. The DFB-LD 4 emits a light having a wavelength λ4 which is different from the wavelength λ3. The lights emitted from the DFB-LDs 3 and 4 are inputted to the optical switch 6a through the coupler 5b connected to the DFB-LDs 3 and 4.

[0031] The large and small relationship between the wavelengths λ1 and λ2 of the lights emitted from the DFB-LDs 1 and 2 and the wavelengths λ3 and λ4 of the lights emitted from the DFB-LDs 3 and 4 satisfies the following inequality (2).

$$\lambda 1\ (\lambda 2) < \lambda 3\ (\lambda 4) \qquad (2)$$

[0032] The difference between the wavelength λ1 (λ2) and the wavelength λ3 (λ4) is sufficiently large. That is, the larger the difference between the wavelength λ1 (λ2) and the wavelength λ3 (λ4) is, the more correctly the sign of the chromatic dispersion distribution is determined.

[0033] The coupler (coupler unit) 5a couples two lights having the wavelengths λ1 and λ2 emitted from the DFB-LDs 1 and 2, respectively. Then, the coupler 5a outputs the coupled light to the optical switch 6a provided in the following position thereof. The coupler 5b couples two lights having the wavelengths λ3 and λ4 emitted from the DFB-LDs 3 and 4, respectively. Then, the coupler 5b outputs the coupled light to the optical switch 6a provided in the following position thereof.

[0034] The optical switch 6a outputs any one of the coupled light based on the lights having the wavalangths λ1 and λ2 outputted from the coupler 5a and tha coupled light based on the lights having tha wavalangths λ3 and λ4 outputted from tha coupler 5b, to the acoustooptic device 7 provided in tha following position thareof.

[0035] The optical switch 6b salects any one of tha optical BPFs 10a and 10b provided in the following positions thereof, as a davice to which each of all reflected lights outputted from the fiber 14 to be measured is inputted. Tharefore, tha optical switch 6b outputs each reflactad light to selected ona of tha optical BPFs 10a and 10b.

[0036] Tha acoustooptic davice 7 forms the waveform of tha light inputted through the optical switch 6a to the pulse form, and outputs the formed pulsa light to the EDFA 8.

[0037] The EDFA (Erbium-Dopad Fibar Amplifier) 8 amplifies the pulse light outputted from tha acoustooptic device 7, and outputs the amplified pulse light to the directionel couplar 9.

[0038] The directional coupler 9 outputs the pulse light amplified by the EDFA 8 to the fiber 14 to ba maasurad. Further, tha directional couplar 9 outputs the FWM light outputted from the fiber 14 to be measured, or the output lights (Harein, thay ara Frasnal reflected lights .) corresponding to lights emitted from tha DFB-LD 1 or 2 and tha DFB-LD 3 or 4 respectively, outputted from tha fiber 14 to be measured, to tha optical switch 6b.

[0039] Tha optical BPF 10a passes a light (Harein, it is either a Stokes ray or an anti-Stokas ray.) having a specific wavelength out of the FWM light caused by lights emitted from the DFB-LDs 1 and 2, outputted from the fibar 14 to be measured.

[0040] The optical BPF 10b passes a light (Herein, it is either a Stokes ray or an anti-Stokas ray.) having a specific wavelangth out of tha FWM light caused by lights emitted from tha DFB-LDs 3 and 4, outputted from tha fiber 14 to be measurad.

[0041] Tha OTDR 11 measures tha loss distribution (the optical fiber chromatic dispersion distribution) for the light inputted into the fiber 14 to be measured, on the basis of the light (tha Stokes ray or tha anti-Stokes ray) passed through the optical BPF 10a or 10b. The OTDR 11 measures the intensity distribution data of the FWM light, shown in FIG. 2.

[0042] The PC (Personal Computer) 12 executes various types of operating processes related to data outputtad from the OTDR 11. In particular, the PC 12 compares tha chromatic dispersion value D1 corresponding to lights emitted from the DFB-LDs 1 and 2 with the chromatic dispersion valua D2 corresponding to lights emitted from the DFB-LDs 3 end 4, in terms of values. Further, the PC 12 measures the propagation times T1 and T2 of the Fresnel reflected lights caused by lights emitted from the DFB-LD 1 or 2 and the DFB-LD 3 or 4 respectivaly, and compares the propagation tima T1 with the propagation time T2, in terms of values.

[0043] Herein, in case the chromatic dispersion value incraases with tha increase of the propagation time oi tha light propagating through the optical fibar 14 to be measured, tha sign of the chromatic dispersion valua of the optical fiber 14 to ba measured is a positiva (+). On the other hand, in case the chromatic dispersion value decreases with tha increase of the propagation tima of the light, the sign of the chromatic dispersion value is a negative (-).

[0044] That is, the PC 12 determines whethar tha optical fiber chromatic dispersion distribution crosses a zero point or not. In casa the PC 12 determinas that the optical fiber chrometic dispersion distribution does not cross the zaro point, the PC 12 determinas whather the sign of the chromatic dispersion value of tha fibar 14 to be measured is a positiva or a negativa on tha basis of the relationship between tha chromatic disparsion values D1 and D2 and tha relationship between the propagation timas T1 and T2.

[0045] For axample, in casa the PC 12 determines that the relationship batween tha chromatic dispersion values D1 and D2 satisfies "D1 < D2" , the PC 12 determines the sign of the chromatic dispersion value, as follows. Whan the PC 12 determines that tha ralationship between tha propagation times T1 and T2 satisflas "T1 < T2", tha PC 12 determines that the sign of the chromatic disparsion value is a positive (+). On the other hand, when the PC 12 determines that the relationship between the propagation times T1 and T2 satisfies "T1 > T2", tha PC 12 datermines that the sign of tha chromatic dispersion value is a nagative (-).

[0046] The wavelength measuring unit 13 monitors the waves of the coupled lights outputted from the couplers 5a and 5b.

[0047] When two lights having different wavelengths from each other, emitted from the DFB-LDs 1 and 2 or the DFB-LDs 3 and 4, are supplied to the fiber 14 to be measurad through the directional coupler 9, the FWM light is genarated in tha fibar 14 to be measured, by the interaction between backscattered lights based on tha two lights. Further, on a far surface of the fiber 14 to be measured, the Frasnel reflected light is ganerated by tha mismatch of tha reflective indax.

[0048] Next, the operation of the embodiment will be explained with reference to FIGS. 2 to 4.

[0049] First, with reference to FIGS. 2 and 3, a process for calculating a chromatic dispersion distribution in the fiber 14 to be measured, on the basis of e waveform data of the FWM light outputted from tha OTDR 11, will be explained.

[0050] FIG. 2 is a graph showing an intensity distribution of the FWM light outputtad from the OTDR 11. FIG. 3 is a flow chart for explaining the process for calculating a chromatic dispersion distribution in the optical fiber 14 to be measured, in the optical fiber chromatic dispersion distribution measuring apparatus 100.

[0051] In FIG. 2, an ebscissa axis represents a transmission distance (km; kilometer) in which the FWM light

outputted from the OTDR 11 is transmitted through the fiber 14 to be measured. An ordinate axis represents an intensity (dB; decibel) of the FWM light, that is, an OTDR signal outputted from the OTDR 11.

[0052] As shown in FIG. 2, the intensity distribution data of the FWM light outputted from the OTDR 11 to the PC 12 shows the intensity of the FWM light transmitted from each point of the fiber 14 to be measured, as a function of the transmission distance. That is, the intensity distribution data cyclically varies (oscillates) with the transmission distance. Therefore, it is possible that the transmission distance corresponds to the phase θ (λ) in the cyclic variation (oscillation) of the intensity distribution.

[0053] As shown in FIG. 3, the PC 12 executes the fast Fourier transform (FFT) of the intensity distribution data of the FWM light outputted from the OTDR 11, in order to calculate the data expressed by a frequency spectrum (Step S1). Next, the PC 12 executes the inverse Fourier transform (inverse FFT) of only the data at positive frequencies in a plurality of the data expressed by the frequency spectrum (Step S2). Thereby, the PC 12 calculates the data having the phase shifted by 90° from the original intensity distribution data of the FWM light (Step S3).

[0054] Then, the PC 12 plots the data obtained in the Step S3 on a complex plane (Step S4). The PC 12 calculates a phase difference Δθ(λ) between each two adjacent plotted data (Step S5). Therefore, the PC 12 calculates a chromatic dispersion value in accordance with the calculated phase difference Δθ(λ).

[0055] Herein, the chromatic dispersion value calculated as described above is an absolute value, that is, a positive value.

[0056] Next, with reference to FIGS. 2 and 4, a process for determining the sign of the chromatic dispersion value will be explained. FIG. 4 is a flow chart for explaining the process for determining the sign of the chromatic dispersion value, in the optical fiber chromatic dispersion distribution measuring apparatus 100.

[0057] As shown in FIG. 4, the PC 12 confirms that the chromatic dispersion distribution value of the fiber 14 to be measured, calculated in accordance with the intensity dispersion data of the FWM light outputted from the OTDR 11 does not cross a zero point (Step S10).

[0058] Then, the PC 12 measures the chromatic dispersion value D1 of the FWM light caused by the lights having the wavelengths λ1 and λ2, emitted from the DFB-LDs 1 and 2 and inputted through the optical BPF 10a and so on. Further, the PC 12 measures the chromatic dispersion value D2 of the FWM light caused by the lights having the wavelengths λ3 and λ4, emitted from the DFB-LDs 3 and 4 and inputted through the optical BPF 10b and so on (Step S11).

[0059] Then, the PC 12 measures the propagation time (time to come back from the Fresnel reflected point) T1 of the Fresnel reflected light caused by the light having the wavelength λ1 or λ2, emitted from the DFB-LD 1 or 2 according to the operation of the optical switch 6a, in the optical fiber 14 to be measured. Then, the PC 12 measures the propagation time T2 of the Fresnel reflected light caused by the light having the wavelength λ3 or λ4, emitted from the DFB-LD 3 or 4 according to the operation of the optical switch 6a, in the fiber 14 to be measured (Step S12).

[0060] Then, the PC 12 determines whether the chromatic dispersion value D2 is larger than the chromatic dispersion value D1 or not (Step S13).

[0061] In Step S13, in case the PC 12 determines that the chromatic dispersion value D2 is larger than the chromatic dispersion value D1 (Step S13; Y), the PC 12 determines whether the propagation time T2 is longer than the propagation time T1 or not, wherein the propagation times T1 and T2 are measured in Step S12 (Step S14).

[0062] In Step S14, in case the PC 12 determines that the propagation time T2 is longer than the propagation time T1 (Step S14; Y), the PC 12 determines the sign of the chromatic dispersion distribution value in the fiber 14 to be measured to be a positive (+) (Step S15). In case the PC determines that the propagation time T2 is not longer than the propagation time T1, that is, the propagation time T1 is longer than the propagation time T2 (Step S14; N), the PC 12 determines the sign of the chromatic dispersion distribution value in the fiber 14 to be measured to be a negative (-) (Step S16).

[0063] In step S13, in case the PC 12 determines that the chromatic dispersion value D2 is not larger than the chromatic dispersion value D1, that is, the chromatic dispersion value D1 is larger than the chromatic dispersion value D2 (Step S13; N), the PC 12 determines whether the propagation time T1 is longer than the propagation time T2 or not, whether the propagation times T1 and T2 are measured in Step S12 (Step S17).

[0064] In Step S17, in case the PC 12 determines that the propagation time T1 is longer than the propagation time T2 (Step S17; Y), the PC 12 determines the sign of the chromatic dispersion distribution value in the fiber 14 to be measured to be a positive (+) (Step S18). In case the PC determines that the propagation time T1 is not longer than the propagation time T2, that is, the propagation time T2 is longer than the propagation time T1 (Step S17; N), the PC 12 determines the sign of the chromatic dispersion distribution value in the fiber 14 to be measured to be a negative (-) (Step S19).

[0065] As described above, the optical fiber chromatic dispersion distribution measuring apparatus 100 to which the present invention is applied comprises four DFB-LDs 1 to 4 as light sources in order to determine the chromatic dispersion distribution of the fiber 14 to be measured and the sign of the chromatic dispersion distribution. The optical fiber chromatic dispersion distribution measuring apparatus 100 measures the propagation times T1 and T2 of the Fresnel reflected lights caused by the lights emitted from the DFB-LD 1 or 2 and the DFB-LD 3 or 4 respectively.

[0066] The optical fiber chromatic dispersion distribution measuring apparatus 100 determines the sign of the chromatic dispersion distribution to be a positive (+) in case the chromatic dispersion value D2 is larger than the chromatic dispersion value D1 and the propagation time T2 is longer than the propagation time T1, or in case the chromatic dispersion value D1 is larger than the chromatic dispersion value D2 and the propagation time T1 is longer than the propagation time T2. On the other hand, the optical fiber chromatic dispersion distribution measuring apparatus 100 determines the sign of the chromatic dispersion distribution to be a negative (-) in case except the above-described case.

[0067] The chromatic dispersion distribution measuring apparatus according to an earlier development can measure only the absolute value of the chromatic dispersion distribution in the fiver 14 to be measured. However, because the chromatic dispersion distribution measuring apparatus according to the present invention further comprises two DFB-LDs 3 and 4 and two optical switches 6a and 6b, it is possible that the chromatic dispersion distribution measuring apparatus determines the sign of the chromatic dispersion distribution easily.

[0068] That is, it is possible to provide the optical fiber dispersion distribution measuring apparatus 100 comprising a superior functionality of easily determining the sign of the chromatic dispersion distribution, without further providing an apparatus for determining the sign of the chromatic dispersion distribution to the measuring apparatus and complicating the structure of the whole measuring apparatus.

[0069] According to the present invention, some effects will be indicated, as follows.

[0070] As described above, it is possible to realize a chromatic dispersion distribution measuring apparatus having a high functionality, without providing an apparatus for determining the sign of the chromatic dispersion value of the optical device to be measured, to the chromatic dispersion distribution measuring apparatus.

[0071] Further, it is possible to measure the chromatic dispersion distribution on the basis of the sign of the chromatic dispersion value of the optical device to be measured, without providing an apparatus for determining the sign of the chromatic dispersion value of the optical device to be measured, to the chromatic dispersion distribution measuring apparatus. Consequently, it is possible to realize a chromatic dispersion distribution measuring apparatus having a further high functionality of outputting correct chromatic dispersion distribution data.

[0072] The entire disclosure of Japanese Patent Application No. Tokugan 2001-58538 filed on March 2, 2001 including specification, claims drawings and summary are incorporated herein by reference in its entirety.

Claims

1. A chromatic dispersion distribution measuring apparatus, comprising:

    a plurality of light sources for emitting lights having different wavelengths from each other;
    an intensity measuring section for measuring a light intensity of a four-wave mixed light which is caused by any two lights of lights emitted from the plurality of light sources and which is outputted from an optical device to be measured, as a function of a transmission distance in the optical device, when the two lights are inputted into the optical device;
    a chromatic dispersion calculating section for calculating a chromatic dispersion value of the optical device, in accordance with the light intensity measured by the intensity measuring section, as the function of the transmission distance;
    a time measuring section for measuring a propagation time of a reflected light which is caused by each light of lights emitted from the plurality of light sources and which is transmitted from a predetermined point in the optical device, when each light is inputted into the optical device; and
    a sign determining section for determining a sign of the chromatic dispersion value of the optical device, on the basis of two different chromatic dispersion values calculated by the chromatic dispersion calculating section, and two propagation times of reflected lights caused by two lights related to the two chromatic dispersion values respectively, of lights emitted from the plurality of light sources.

2. The chromatic dispersion distribution measuring apparatus as claimed in claim 1, further comprising:

    a chromatic dispersion distribution calculating section for calculating a chromatic dispersion distribution with a sign, of the optical device, in accordance with the sign of the chromatic dispersion value of the optical device, determined by the sign determining section.

3. A chromatic dispersion distribution measuring method, comprising:

    emitting a plurality of lights having different wavelengths from each other;
    measuring a light intensity of a four-wave mixed light which is caused by any two lights of the plurality of lights and which is outputted from an optical device to be measured, as a function of a transmission distance in the optical device,

when the two lights are inputted into tha optical devica;
calculating a chromatic dispersion valua of the optical device, in accordance with tha light intensity measured as the function of the transmission distance;
measuring a propegetion time of a reflected light which is caused by aach light of tha plurality of lights and which is transmitted from a predetermined point in tha optical davice, whan each light is inputted into the optical devica; and
determining a sign of the chromatic dispersion veiue of the optical device, on the basis of two diffarent chrometic dispersion velues and two propagation times of reflected lights caused by two lights related to the two chromatic dispersion values respectively, of tha plureiity of lights.

4. The chromatic disparsion distribution measuring mathod as claimed in claim 3, further comprising:

calculating a chromatic dispersion distribution with a sign, of the optical device, in accordance with tha sign of tha chromatic disparsion valua of tha optical device.

5. A chrometic dispersion distribution measuring apparatus, comprising:

at least four light sources for emitting lights having different wavaiengths from each other;
an intansity measuring section for measuring two diffarant light intensities of two four-wava mixed lights which ara caused by any two peirs of lights of iights emitted from the light sources and which are outputted from an optical device to be measured, as functions of transmission distances in tha optical device, whan tha two pairs of lights are inputted into the optical davica, for avery pair of iights;
a chromatic dispersion calculating section for calculating two differant chrometic disparsion velues of tha optical device, in accordance with tha two light intansities measured by tha intensity maasuring section, respectivaly;
a tima maasuring section for maasuring two different propegation times of two reflected iights one of which is caused by eny one light of ona pair of tha two pairs of lights and transmittad from a predetarminad point in tha optical device, and the other of which is caused by any ona iight of the other peir of tha two pairs of lights and transmitted from a predeterminad point in the optical device, when tha ona light of the ona pair of lights and the ona light of tha other pair of lights are individually inputted into the optical davice; and
a sign determining section for determining a sign of the chromatic dispersion valua of the optical device, on the basis of the two chromatic dispersion values calculated by the chromatic dispersion calculating section, end the two propagation timas measured by the time maasuring section.

6. Tha chromatic dispersion distribution measuring apparatus as claimed in claim 5, furthar comprising:

a chrometic dispersion distribution calculating section for calculating e chromatic disparsion distribution with a sign, of tha optical davice, in accordenca with the sign of the chromatic dispersion value of the optical device, determined by the sign determining section.

7. Tha chromatic dispersion distribution maasuring apparatus as claimed in claim 5, further comprising:

a first opticel switching section for providing any two pairs of lights of lights emitted from the light sources, for every peir of lights, end any one light of ona pair of the two pairs of lights end any ona light of the other pair of tha two pairs of lights, individually, to tha optical device; end
a second optical switching section for providing two four-weve mixed iights ceused by tha two pairs of lights, to the intensity measuring section, individually, and two raflected lights caused by the one light of the one pair of the two pairs of lights and the one iight of the othar pair of the two peirs of iights, to the tima measuring section, individuelly.

8. A chromatic disparsion distribution measuring mathod, comprising:

emitting at least four lights having different wavelengths from each other;
measuring two diffarant light intensitias of two four-wava mixed lights which are caused by any two pairs of lights of tha lights and which are outputted from an optical davice to be measured, as functions of transmission distances in tha optical device, when tha two pairs of lights are inputted into the optical devica, for evary pair of lights;
calcuiating two differant chromatic dispersion valuas of the optical device, in accordanca with tha two light intensities, respectively;
measuring two different propagation times of two reflectad iights one of which is causad by any one light of one pair of the two peirs of lights and transmitted from a pradetermined point in the optical device, and the other of which is causad by any one light of the other pair of the

two pairs of lights and transmitted from a predetermined point in the optical device, when the one light of the one pair of lights and the one light of the other pair of lights are individually inputted into the optical device; and determining a sign of the chromatic dispersion value of the optical device, on the basis of the two chromatic dispersion values and the two propagation times.

9. The chromatic dispersion distribution measuring method as claimed in claim 8, further comprising:

calculating a chromatic dispersion distribution with a sign, of the optical device, in accordance with the sign of the chromatic dispersion value of the optical device.

10. The chromatic dispersion distribution measuring method as claimed in claim 8, further comprising:

providing any two pairs of lights of the lights, for every pair of lights, and any one light of one pair of the two pairs of lights and any one light of the other pair of the two pairs of lights, individually, to the optical device; and providing two four-wave mixed lights caused by the two pairs of lights, individually, to measure two different light intensities, and two reflected lights caused by the one light of the one pair of the two pairs of lights and the one light of the other pair of the two pairs of lights, individually, to measure two different propagation times.

11. A chromatic dispersion distribution measuring apparatus, comprising:

means for emitting at least four lights having different wavelengths from each other; means for measuring two different light intensities of two four-wave mixed lights which are caused by any two pairs of lights of the lights and which are outputted from an optical device to be measured, as functions of transmission distances in the optical device, when the two pairs of lights are inputted into the optical device, for every pair of lights; means for calculating two different chromatic dispersion values of the optical device, in accordance with the two light intensities, respectively; means for measuring two different propagation times of two reflected lights one of which is caused by any one light of one pair of the two pairs of lights and transmitted from a predetermined point in the optical device, and the other of which is caused by any one light of the other pair of the two pairs of lights and transmitted from a predetermined point in the optical device, when the one light of the one pair of lights and the one light of the other pair of lights are individually inputted into the optical device; and means for determining a sign of the chromatic dispersion value of the optical device, on the basis of the two chromatic dispersion values and the two propagation times.

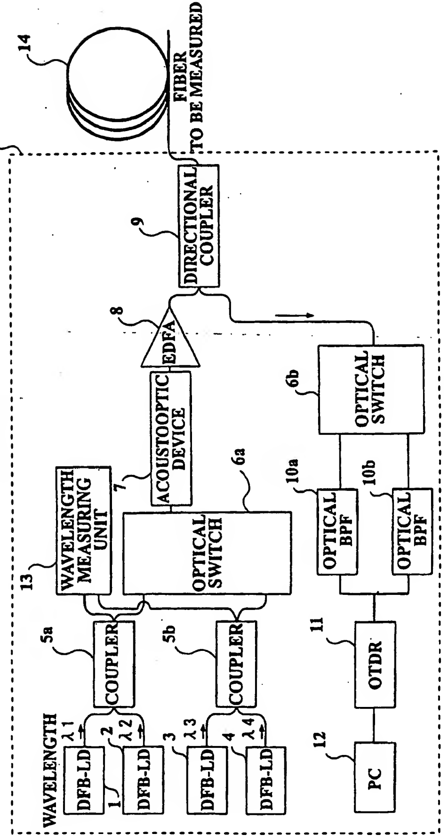
12. The chromatic dispersion distribution measuring apparatus as claimed in claim 11, further comprising:

means for calculating a chromatic dispersion distribution with a sign, of the optical device, in accordance with the sign of the chromatic dispersion value of the optical device.

13. The chromatic dispersion distribution measuring apparatus as claimed in claim 11, further comprising:

means for providing any two pairs of lights of the lights, for every pair of lights, and any one light of one pair of the two pairs of lights and any one light of the other pair of the two pairs of lights, individually, to the optical device; and means for providing two four-wave mixed lights caused by the two pairs of lights, individually, to measure two different light intensities, and two reflected lights caused by the one light of the one pair of the two pairs of lights and the one light of the other pair of the two pairs of lights, individually, to measure two different propagation times.

FIG.1



100
14
FIBER
TO BE MEASURED
9
DIRECTIONAL
COUPLER
8
EDFA
7
ACOUSTOOPTIC
DEVICE
6a
OPTICAL
SWITCH
6b
OPTICAL
SWITCH
13
WAVELENGTH
MEASURING
UNIT
10a
OPTICAL
BPF
10b
OPTICAL
BPF
5a
COUPLER
5b
COUPLER
11
OTDR
12
PC
WAVELENGTH
λ1
λ2
λ3
λ4
1
2
3
4
DFB-LD
DFB-LD
DFB-LD
DFB-LD

FIG.2

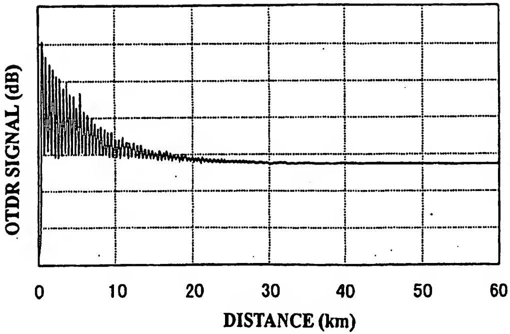


FIG.3

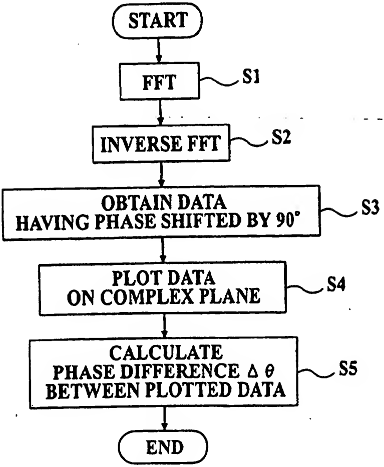
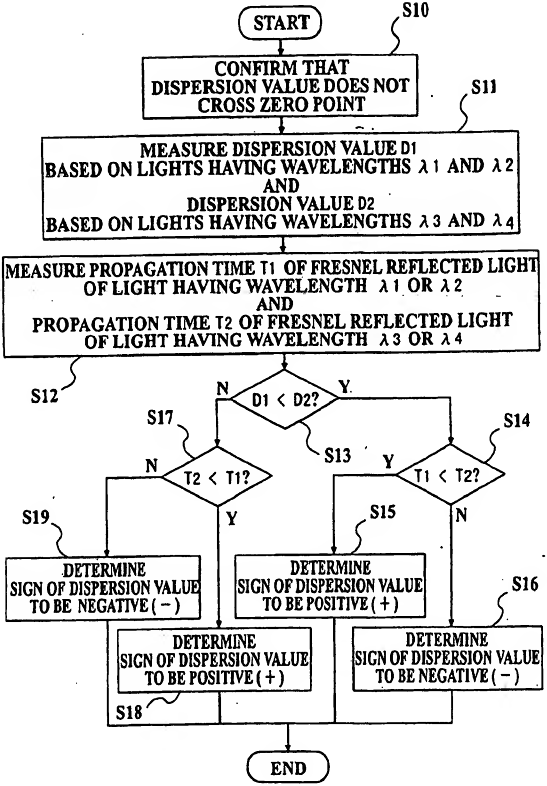

START
FFT
S1
INVERSE FFT
S2
OBTAIN DATA
HAVING PHASE SHIFTED BY 90°
S3
PLOT DATA
ON COMPLEX PLANE
S4
CALCULATE
PHASE DIFFERENCE Δ θ
BETWEEN PLOTTED DATA
S5
END

FIG.4


START
S10
CONFIRM THAT DISPERSION VALUE DOES NOT CROSS ZERO POINT
S11
MEASURE DISPERSION VALUE D1 BASED ON LIGHTS HAVING WAVELENGTHS λ1 AND λ2 AND DISPERSION VALUE D2 BASED ON LIGHTS HAVING WAVELENGTHS λ3 AND λ4
MEASURE PROPAGATION TIME T1 OF FRESNEL REFLECTED LIGHT OF LIGHT HAVING WAVELENGTH λ1 OR λ2 AND PROPAGATION TIME T2 OF FRESNEL REFLECTED LIGHT OF LIGHT HAVING WAVELENGTH λ3 OR λ4
S12
D1 < D2?
N
Y
S13
S17
T2 < T1?
N
Y
S14
T1 < T2?
Y
N
S19
DETERMINE SIGN OF DISPERSION VALUE TO BE NEGATIVE (−)
S15
DETERMINE SIGN OF DISPERSION VALUE TO BE POSITIVE (+)
S16
DETERMINE SIGN OF DISPERSION VALUE TO BE POSITIVE (+)
DETERMINE SIGN OF DISPERSION VALUE TO BE NEGATIVE (−)
S18
END